

Anatomical variations of cystic artery: A digital subtraction angiography study

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Ethics Committee Approval

Ethics committee approval was received from Ankara University Local Ethics Committee (H10-658-20).

All procedures in this study involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments.

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Conflict of Interest

No conflict of interest was declared by the authors.

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Abstract

Background/Aim: Branching variations in the cystic and hepatic arteries may lead to bleeding and mortal complications during surgery. This study aimed to demonstrate the relationship between cystic artery (CA) variations and hepatic artery branching patterns among an Anatolian population using Michel's classification and compare the distribution of these variations among genders.

Methods: Angiographies performed between 2014-2017 were retrospectively evaluated and DSA images of 303 patients (84 females and 219 males) were included in this cross-sectional study. Michel's classifications of the hepatic arteries and CA variations of the patients were noted, and each was analyzed separately, along with gender-related branching differences.

Results: Hepatic arteries of 256 patients could be evaluated according to Michel's classification, the most frequent being Michel's class I (69.9 %). Thirty patients (9.9%) were excluded from CA-related statistical analyses since they had undergone a cholecystectomy. CAs were not visualized in fifty-five (18.2%) of the remaining patients. Of the 218 patients with apparent CAs, eleven females (19.3%) and twenty males (12.4%) had double cystic arteries ($P=0.201$). Two hundred and twelve (85.1%) CAs originated from the right hepatic artery (RHA), which was the most common parent artery. No significant relationship was found between Michel's classification and CA origin among different genders ($P=0.532$).

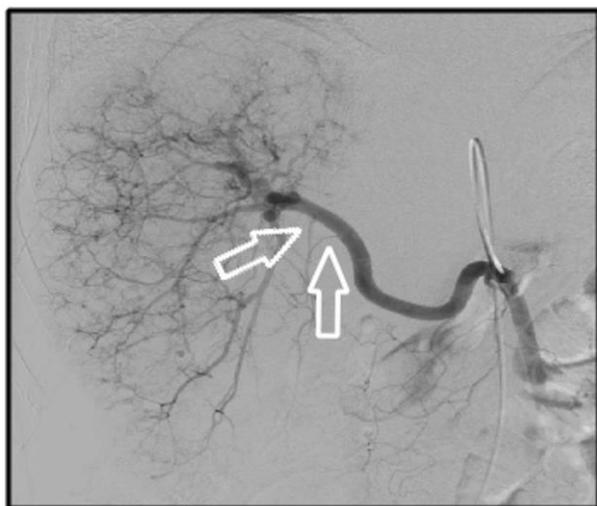
Conclusion: An overlooked anatomic variation could lead to many iatrogenic complications during diagnostic and therapeutic interventions; thus, variations of the vascular structures have attracted medical professionals' interest. This study focuses on the variations of the cystic artery and its relationship with hepatic arterial branching variations.

Keywords: Cystic artery, Michel's classification, Digital subtraction angiography, Variation

Introduction

The celiac trunk is the first ventral branch of the abdominal aorta which usually originates at about the 12th thoracic vertebra level. It divides into left gastric, common hepatic, and splenic arteries. The common hepatic artery (CHA) then gives rise to its two terminal branches: The proper hepatic artery (PHA) and the gastroduodenal artery (GDA). Proper hepatic artery soon divides into right and left hepatic arteries. In some individuals, the right hepatic artery (RHA) arises from the superior mesenteric artery (SMA) and is named “aberrant right hepatic artery” (abRHA). The left hepatic artery (LHA) stemming from the left gastric artery (LGA) is called the aberrant left hepatic artery (abLHA). The CA typically arises from RHA and then bifurcates into superficial and deep branches to supply the gallbladder and the cystic duct. Superficial and deep branches supply peritoneal and nonperitoneal surfaces of the gallbladder, respectively. In 25% of individuals, the superficial and deep branches of the cystic artery can arise from different arterial origins. Michel called them “double cystic arteries” (Figure 1) [1-3].

Figure 1: Digital Subtraction Angiography images of double cystic artery



The complex vascular anatomy of the liver was presented in detail in Michel’s classification. Origin of the CA and branching pattern of the hepatic arteries from the nearby vessels vary widely [4]. Variations of the CA are a critical issue for surgeons, interventional radiologists, and anatomists. These variations may have clinically important consequences.

Variations of CA and branching pattern of the hepatic arteries in a sample of an Anatolian population were analyzed and presented in this study.

Materials and methods

Patients with selective celiac and superior mesenteric angiographies were included in this retrospective study, for which approval was obtained from Ankara University Local Ethics Committee (I10-658-20). Patients with a history of hepatic resection/surgery, prior cholecystectomy, prior hepatic arterial embolization (Transarterial chemo/radioembolization) were excluded. Digital subtraction angiographic (DSA) images of 303 patients obtained between 2014-2017 were evaluated for hepatic arterial branching patterns and CA variations. The patients’ ages, genders, branching types of the hepatic artery, and CA variations were recorded and statistically analyzed.

All DSA images were obtained with a dedicated device (Artis Zee Floor, Siemens, Erlangen, Germany) under local anesthesia to evaluate the vascular anatomy. The common femoral artery was punctured for catheterization and 5F catheters (Cobra or Simmons, Boston Scientific, Natick, MA, USA) were used for selective celiac and superior mesenteric angiographies. A coaxial microcatheter (Progreat, 2.7F, Terumo, Tokyo, Japan) was used whenever needed by the operator. A nonionic contrast medium (Xenetix 350 mg/ml, Guerbet, France) was injected through a power injector (Medrad, Indianola, Pennsylvania, USA) while patients were holding their breath during celiac or superior mesenteric angiographies. The injection parameters for celiac and superior mesenteric angiographies had a total contrast media volume of 15-21 ml with an injection rate of 5-7 ml/s.

Statistical analysis

The variables were presented as minimum-maximum values, mean, standard deviation, frequency, and percentage. Pearson chi-square and Fisher exact tests were used to assess categorical variables. The statistical analyses were performed with IBM SPSS (version 20). $P < 0.05$ was considered statistically significant in all tests.

Results

A total of 303 patients (84 females, 219 males) were included in this study. The median age of the patients was 60.45 (11.38) years (17 – 90 years) (Table 1).

The CAs of 57 females and 161 males could be visualized, totaling 218 patients. The most frequent origin of CA was the RHA (n=212, 85.1%) (Table 2) (Figure 2). Double CAs were found in 31 (14.2%) patients, eleven (19.3%) females, and twenty (12.4%) males (Table 3). CAs of 85 patients could not be visualized either because of a previous cholecystectomy (9.9%) or technical inadequacy (18.2%). The number of CAs was similar between males and females ($P=0.201$).

Table 1: Demographic variables

| Variables | Mean (SD) (Min-Max) |
|-----------|-----------------------|
| Age | 60.45 (11.38) (17-90) |
| Gender | n(%) |
| Female | 84 (27.7%) |
| Male | 219 (72.38%) |
| Total | 303(100%) |

Table 2: Origin of cystic artery

| Origin of cystic artery | n (%) |
|-------------------------|------------|
| RHA | 212 (85.1) |
| abRHA | 10 (4.0) |
| PHA bif. | 1 (0.4) |
| PHA | 6 (2.4) |
| LHA | 3 (1.2) |
| abLHA | 4 (1.6) |
| CHA | 5 (2.0) |
| GDA | 7 (2.8) |
| unclassified | 1 (0.4) |

RHA: Right hepatic artery, abRHA: aberrant right hepatic artery, PHA bif: proper hepatic artery bifurcation, PHA: proper hepatic artery, LHA: left hepatic artery, abLHA: aberrant left hepatic artery, CHA: common hepatic artery, GDA: gastroduodenal artery

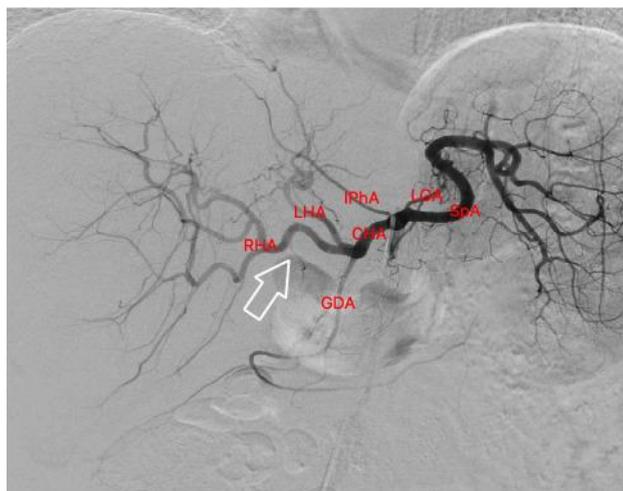
Table 3: Comparison of cystic artery number between males and females

| Number of cystic arteries | Female (n%) | Male (n%) | P-value |
|---------------------------|-------------|------------|---------|
| Single | 46 (80.7) | 141 (87.6) | 0.201 |
| Double | 11 (19.3) | 20 (12.4) | |

The hepatic arteries of 256 patients were categorized by Michel’s classification, and Michel’s class I was the most frequent branching pattern (69.9%) (Table 4) (Figure 3). Michel’s classification distributions of the hepatic arteries among different genders were similar ($P=0.532$). Forty-seven (15.5%) patients’ hepatic arterial branching patterns were not analyzed due to prior hepatic surgeries or because of an unclassified branching pattern

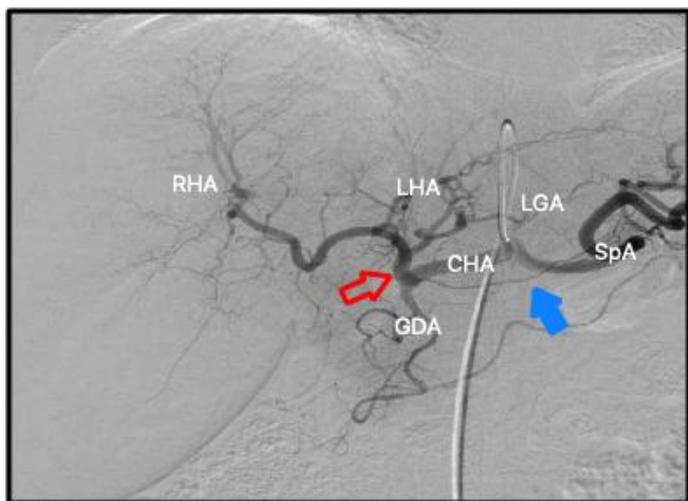
according to Michel's classification. No significant relationship was found between Michel's classification and CA origin ($P < 0.001$) (Table 5).

Figure 2: CA originated from the RHA



White arrow: Cystic artery (CA), Right hepatic artery (RHA), left hepatic artery (LHA), common hepatic artery (CHA), gastroduodenal artery (GDA), left gastric artery (LGA), splenic artery (SpA), inferior phrenic artery (IPhA)

Figure 3: Michel type I



Blue arrow: Right gastric artery, Red arrow: Proper hepatic artery, Right hepatic artery (RHA), left hepatic artery (LHA), common hepatic artery (CHA), gastroduodenal artery (GDA), left gastric artery (LGA), splenic artery (SpA)

Table 4: Distribution of cases according to Michel's classification

| | Female n (%) | Male n (%) | Total n (%) |
|------|--------------|------------|-------------|
| I | 45 (66.2) | 134 (71.3) | 179(69.9) |
| II | 7 (10.3) | 17 (9.0) | 24 (9.4) |
| III | 7 (10.3) | 15 (8.0) | 22 (8.6) |
| IV | 2 (2.9) | 3 (1.6) | 5 (2) |
| V | 4 (5.9) | 13 (6.9) | 17 (6.6) |
| VI | 0 | 4 (2.1) | 4 (1.6) |
| VIII | 2 (2.9) | 1 (0.5) | 3 (1.2) |
| IX | 1 (1.5) | 1 (0.5) | 2 (0.8) |

Table 5: Relationship between Michel's classification and origin of cystic artery

| Michel's classification | Origin of cystic artery n (%) | | | | | | | |
|-------------------------|-------------------------------|--------|---------|---------|---------|---------|---------|---------|
| | RHA | abRHA | bif PHA | PHA | LHA | abLHA | CHA | GDA |
| I | 133 (89.9) | - | - | 4 (2.7) | 1 (0.7) | - | 5 (3.4) | 5 (3.4) |
| II | 13 (81.2) | - | 1 (6.2) | 1 (6.2) | - | - | - | 1 (6.2) |
| III | 12 (60) | 7 (35) | - | - | 1 (5.0) | - | - | - |
| IV | 3 (100) | - | - | - | - | - | - | - |
| V | 13 (86.7) | - | - | - | 1 (6.7) | 1 (6.7) | - | - |
| VI | 3 (75) | 1 (25) | - | - | - | - | - | - |
| VIII | 2 (100) | - | - | - | - | - | - | - |
| IX | 2 (100) | - | - | - | - | - | - | - |

RHA: Right hepatic artery, abRHA: aberrant right hepatic artery, PHA bif: proper hepatic artery bifurcation, PHA: proper hepatic artery, LHA: left hepatic artery, abLHA: aberrant left hepatic artery, CHA: common hepatic artery, GDA: gastroduodenal artery

Discussion

Variations of the vascular structures and recognition of these variations are of grave importance in diagnostic and therapeutic procedures. An unnoticed anatomic variation could lead to numerous life-threatening pitfalls during surgical or

interventional treatments. Thus, vascular variations have attracted medical professionals' interest and have always been the center of interest of many specialties.

There are many studies in the literature presenting hepatic vascular or CA variations separately [4-9]. Procedures like hepatic tumor resection, transplantation, trans-arterial chemo/radioembolization require a complete detailed assessment of hepatic and cystic vessel anatomy and their variants. Many inadvertent consequences including inadequate embolization, iatrogenic tissue necrosis, or life-threatening intraoperative hemorrhage may only be prevented by proper evaluation and recognition of the anatomy of the intended vessel. Therefore, CA and hepatic arterial variations were analyzed in this study.

Uğurel et al. [10] and Du et al. [11] analyzed hepatic arterial branching and reported the most frequent branching pattern as Michel's class I with 52%, and 76.3% prevalence, respectively. In terms of Michel's classification, the results of our study are in concordance with the mentioned literature. In their review, Andall et al. evaluated the origin of CA, also stating similar results to our study in terms of the parent artery of CA [12].

Laparoscopic cholecystectomy is preferred over open surgery for the treatment of gallbladder diseases. However, bleeding is still a common complication of the procedure. Because of the narrow visual field of operation site and CA variations, intraoperative dissection of Calot's triangle requires advanced surgical experience. The Calot triangle which is bounded by the common hepatic duct, cystic duct, and the undersurface of the liver, accommodates several tiny cystic arteries [13-15]. 1.5 per 1000 laparoscopic cholecystectomy procedures were converted to open surgery because of hemorrhagic complications related to the CA injuries [12, 16, 17]. The link between Michel's classification and CA origin was evaluated in the current study. Although no significant relationship between Michel's classification and CA origin was found, Michel's 3rd group had the least rate of RHA as a parent artery of cystic artery among all Michel's groups (60%). This should be remembered when performing laparoscopic cholecystectomies to patients with RHAs originating from the superior mesenteric artery. We speculate that hemorrhagic complications occurring during laparoscopic cholecystectomies could potentially be related to double or single cystic arteries originating from an artery other than the RHA. Studies conducted with larger sample sizes will yield more accurate findings.

Mlakar et al. [8] and Kang et al. [18] reported that double CAs were observed in 14-25% of individuals among different populations. Double CA prevalence was 14.2% in our study, which was consistent with the literature. We also investigated gender-based differences in double CAs. Despite the insignificant difference, there was a slight female predominance (19.3% vs. 12.4%).

Bakheit et al. [19] and Saidi et al. [20] analyzed the position of CA with regards to the cystic, hepatic, and bile ducts. Our research was not this thorough in this regard, which may be considered a limitation. However, our study is from the view of endovascular radiology. The percutaneous endovascular approach provides a targeted treatment without damaging the neighboring structures.

There are many options to evaluate CA variations, including ultrasound imaging, computed tomography

angiography, magnetic resonance angiography, digital subtraction angiography, operative and cadaver dissections [4, 13, 18, 21-25]. In the present study, CA variations were analyzed by DSA images. Small-sized vessels in the abdominal cavity may be misinterpreted by some imaging methods because of the superposing and intermingling tissue and structures. They are also likely to be damaged in operative or cadaver dissections. DSA is the gold standard of vascular imaging and allows visualization of the branching patterns of the vascular territory. It is also useful in isolating the artery of interest from other tissues while preventing iatrogenic damage to the vessels, all of which add value to the present study.

Limitations

The retrospective nature is the most important limitation of this study. Another limitation could be the patient population which mainly consisted of patients with tumors. Since patients with prior interventions to the coeliac and superior mesenteric arterial axis were excluded from data analyses, this potential limitation has been neglected. Although the present work includes complementary data about the missing points of the previous studies in the literature, a larger number of cases are required for significant results.

Conclusions

Studies on regional differences give a preliminary idea to the clinicians and the scientific literature contains a rich archive of studies for all types of anatomical variations. An unnoticed variation could lead to many complications during therapeutic interventions, which could be prevented with the recognition of anatomic variations during diagnostic imaging. Our work serves as valuable data to further understand the cystic artery anatomy in an Anatolian population.

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